AD-A105 629 DECISIONS AND DESIGNS INC MCLEAN VA F/G 5/10
VALUE TREE ANALYSIS OF ENERGY SUPPLY ALTERNATIVES.(U)
JUN 81 W G STILLWELL, D V WINTERFELDT MDA903-80-C-0194

UNCLASSIFIED NL

1 of 1

END
DATE
FILMED
11-81
DTIC

AD A105629

(9) TECHNICAL RE[redacted]T SSRI 81-2

(6) VALUE TREE ANALYSIS OF ENERGY SUPPLY ALTERNATIVES

(12) 421

BY

(10) WILLIAM G. STILLWELL

DETLOF VON WINTERFELDT

~~AND~~

RICHARD S. JOHN

SPONSORED BY

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

(15) PRIME CONTRACT MDA903-80-C-0194

UNDER SUBCONTRACT FROM

DECISIONS AND DESIGNS, INCORPORATED

(11) JUNE ~~19~~81

SOCIAL SCIENCE RESEARCH INSTITUTE
UNIVERSITY OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA 90007

390664 [illegible]

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SSRI 81-2	2. GOVT ACCESSION NO. AD-	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Value Tree Analysis of Energy Supply Alternatives		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER SSRI 81-2
7. AUTHOR(s) William G. Stillwell, Detlof von Winterfeldt, and Richard S. John		8. CONTRACT OR GRANT NUMBER(s) Prime Contract MDA903-80-C-0194
9. PERFORMING ORGANIZATION NAME AND ADDRESS Social Science Research Institute University of Southern California University Park, Los Angeles, CA 90007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency DSO/CTD, 1400 Wilson Boulevard Arlington, VA 22209		12. REPORT DATE June, 1981
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Decisions & Desings, Inc. 8400 Westpark Drive, Suite 600; P.O. Box 907 McLean, VA 22101		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

energy options
energy supply alternatives
hierarchical and non-hierarchical weighting procedures
weights
attibutes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study examined the use of value trees in multiattribute evaluations of energy supply alternatives. A value tree relating general values and concerns to specific value relevant attributes was constructed to compare three energy options: nuclear, coal, and a combined geothermal and conservation package. Thirty-seven subjects weighted the importance of the attributes in the tree using both hierarchical and non-hierarchical weighting procedures, and they rated the energy options on all attributes and all levels of the tree. From these importance weights and ratings several additive multiattribute models were constructed and compared with

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

holistic rankings and ratings of the three options.

The experiment had three basic findings: first, hierarchical weights were steeper (higher weight ratios) than non-hierarchical weights. Second, groups identified by their holistic first choice showed substantial agreement in their assessment of attribute weights. Attribute-wise ratings of energy options also agreed rather well across groups, although there was a tendency for each group to favor their holistic first choice. This convergence of MAU model parameters resulted in a "common model" that was rather consistent with holistic evaluations of the pro-conservation group, and generally inconsistent with those of the pro-nuclear group. This third finding of differential consistency between model composites and holistic evaluations is interpreted as a result of weight parameter distortions due to social desirability and a neglect to consider attribute value ranges when making weight judgments.

Summary

This study examined the use of value trees in multiattribute evaluations of energy supply alternatives. A value tree relating general values and concerns to specific value relevant attributes was constructed to compare three energy options: nuclear, coal, and a combined geothermal and conservation package. Thirty-seven subjects weighted the importance of the attributes in the tree using both hierarchical and non-hierarchical weighting procedures, and they rated the energy options on all attributes and all levels of the tree. From these importance weights and ratings several additive multiattribute models were constructed and compared with holistic rankings and ratings of the three options.

The experiment had three basic findings: First, hierarchical weights were steeper (higher weight ratios) than non-hierarchical weights. Second, groups identified by their holistic first choice showed substantial agreement in their assessment of attribute weights. Attribute-wise ratings of energy options also agreed rather well across groups, although there was a tendency for each group to favor their holistic first choice. This convergence of MAU model parameters resulted in a "common model" that was rather consistent with holistic evaluations of the pro-conservation group, and generally inconsistent with those of the pro-nuclear group. This third finding of differential consistency between model composites and holistic evaluations is interpreted as a result of weight parameter distortions due to social desirability and a neglect to consider attribute value ranges when making weight judgments.

Figures

Page

Tables

Contents

Acknowledgement

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Office of Naval Research, Prime Contract MDA903-80-C-0194 under subcontract from Decisions and Designs, Inc.

I. Introduction

Complex evaluation problems can be structured by building a value tree (Edwards, 1980), objectives hierarchy (Keeney and Raiffa, 1976), or analytic hierarchy (Saaty, 1977). These are essentially equivalent semantic structures that relate general values and concerns of the evaluator to specific attributes descriptive of the alternatives under consideration. Value trees are usually displayed in pyramid format with a small number of general value labels at the top level, several intermediate level objectives, and a larger number of specific value relevant attributes at the bottom level. The lowest level attributes (twigs) serve to explicate and operationalize higher level values and concerns. Figure 1 shows a schematic example of a simple value tree with two objectives and seven twigs.

Insert Figure 1 about here

Edwards (1977) proposed the following procedure for evaluating alternatives with respect to the attributes of a value tree. First, the performance of each alternative x is defined on each attribute A_i via single attribute ratings $v_i(x)$. Next, a weight w_i is assigned to each attribute, reflecting its "relative importance" in the evaluation. Finally, weights and single attribute ratings are combined into an overall evaluation of each alternative by an additive model:

$$v(x) = \sum_{i=1}^{n} w_i v_i(x) \qquad (1)$$

While equation (1) is usually defined using the twigs of a value tree, alternative procedures exist which exploit the hierarchical structure of the tree. First, equation (1) can be applied to higher

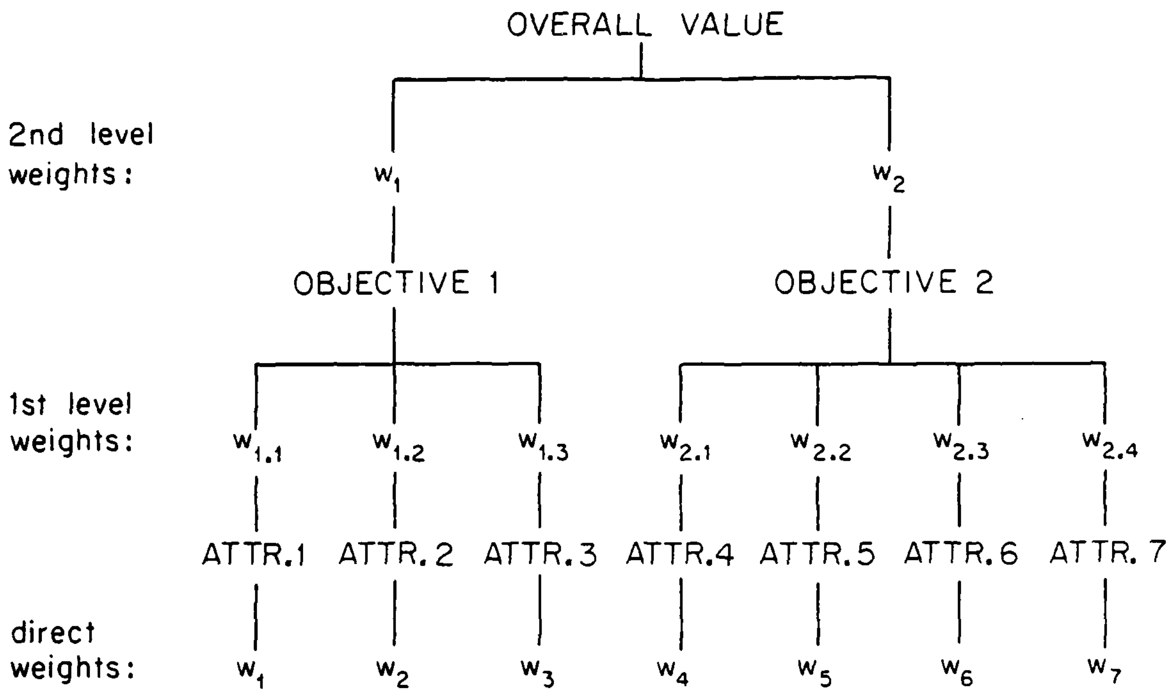

Figure 1: Schematic Value Tree

levels of the tree. In the value tree structure of Figure 1, for example, one could build a model on the level of the two objectives, rather than on the level of the seven twigs. A second option is to assess weights at different levels of the tree, considering only branches that belong to the same node. Weights for any particular level can then be obtained by multiplying these "conditional" weights down the tree. In the value tree of Figure 1, for example, one would first weight attributes 1-3 with respect to objective 1, then weight attributes 4-7 with respect to objective 2, and finally assign relative weights to the two objectives. Multiplying first level and second level weights would produce the relevant twig weights.

To distinguish among possible combinations of models, we will refer to a "k-th level model" whenever the alternatives were rated on the k-th level of attributes. We will refer to a "hierarchical model" whenever weights were obtained by multiplying conditional weights down the tree. In a non-hierarchical model, in contrast, all attributes at a given level are weighted simultaneously.

In general, decision analysts favor lower level models, because single attribute ratings are simpler for specific attributes. Higher level models are sometimes used for consistency checks, but it is assumed that lower level models provide more valid representations of the evaluator's preferences. Whether to use a hierarchical or non-hierarchical model is a more tricky question. Advocates of hierarchical procedures argue that the semantic structure of the value tree provides a convenient frame for comparing values and objectives, since it requires importance judgments only within relatively small sets of objectives and attributes at comparable levels of abstraction.

But there are also potential problems. Hierarchical weighting assumes that attributes under each node are independent and describe the node exhaustively. However, some attribute sets may not be independent, and more abstract attribute labels may not be psychologically equivalent to the set of more concrete attribute labels directly below. Another problem is that weights often depend on the ranges of alternatives on attributes. Unfortunately, such ranges become ill-defined and vague at higher levels of the value tree.

So far there has been very little experimental research on multi-level and/or hierarchical models. Sayeki and Vesper (1973) compared hierarchical and non-hierarchical weighting procedures and found that hierarchical weights are steeper (larger weight ratios between pairs of attributes) than non-hierarchical weights. While no experiment has systematically explored the differences between models built at different levels of the tree, a number of experiments have compared "twig" models with so-called "holistic" assessments, in which the overall value of alternatives is rated directly. Such holistic judgments have been used to derive the implicit weighting policy (through regression or other statistical models) and these implicit weights were compared with directly assessed weights at the twig level. The stable result of this research was that implicit weights are steeper than explicit weights (see, for example, Slovic and Lichtenstein, 1971; John and Edwards, Note 1).

One interpretation of this result is that people concentrate only on the two or three most important attributes when making holistic judgments and neglect the less important ones. Since people with differing value positions typically stress the importance of different

sets of attributes, one would therefore expect more disagreement in their holistic judgments than in their multiattribute model, and perhaps more disagreement among higher level models than among lower level models.

The experiment described in the following sections explored such differences between multilevel hierarchical and non-hierarchical models. The experiment was designed to answer the following questions:

1) Are hierarchical weights systematically different from non-hierarchical weights?
2) Are higher level ratings systematically different from predictions of lower level models?
3) Do lower level models display more (or less) agreement among subjects than higher level models?

To explore these questions, we examined a problem in which subjects had to evaluate three energy supply options on 13 attributes structured in the form of a value tree. This problem is described next.

II. The Energy Supply Scenario and Value Tree

We chose a controversial problem in order to allow subjects' value differences to bear on the evaluation. The problem was how to supply electricity to a region whose population was growing at such a fast rate that the regional utility company's present supply capacity would soon fall short of the demand. The scenario included three alternatives: a 2400 Megawatt[2] (MW) nuclear plant, a 2400 MW coal fired plant, and a smaller geothermal plant (800 MW) with a combined package of strict

conservation measures. Each of the three proposals was summarized on one page, describing the nature of the plant and surrounding environment in general terms. It was stressed that the geothermal plant/conservation package would require intrusive conservation measures, such as direct restrictions on electricity use in peak hours, as well as more passive measures (e.g., tax incentive programs).

Detailed value trees for comparing such energy options had been developed as part of another research project (see, v. Winterfeldt and Otway, 1981). These value trees were elicited from members of groups involved in the energy supply debate: utility company executives, representatives of regulatory agencies, and environmental groups. These group specific value trees were very detailed and included up to 100 twigs. For the purpose of this experiment, we radically pruned these trees and combined them into one joint tree, shown in Figure 2. While we cut the tree well above measurable attribute levels, we attempted to cover all

Insert Figure 2 about here

concerns mentioned in the single group trees. We also attempted to provide relatively specific descriptions of the thirteen twigs. These descriptions are presented in Table 1.

Insert Table 1 about here

III. Method

Subjects. Subjects were 37 undergraduates of the University of Southern California. They received credit for a class requirement for participation.

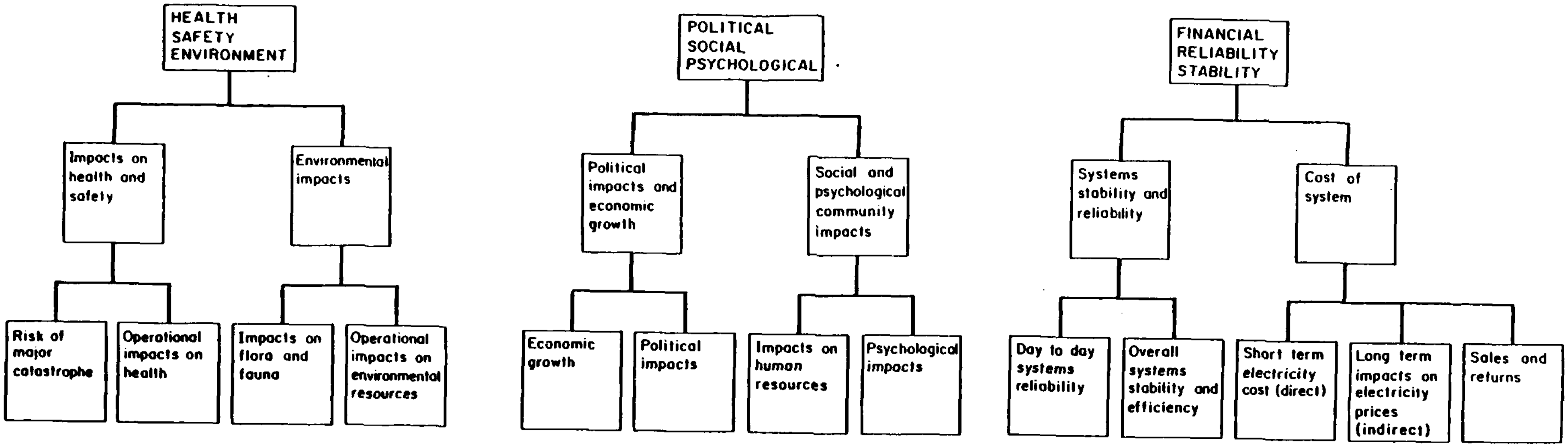

Figure 2: Value Tree for Comparing Energy Options

TABLE 1

DESCRIPTIONS OF ATTRIBUTES

Risks of a major catastrophe: The risks associated with a major accident at the facility (fatalities, short and long term health impacts, loss of land, etc.).

Operational impacts on human health: The short and long term health effects (cancer, asthma, genetic disorders, bronchitis, etc.) of pollution produced by daily operations at the facility.

Impacts on flora and fauna: The impact of the new facility on the ecosystems of various life forms, especially those of endangered species.

Impacts of operations on environmental resources: The impact of the suggested facility on the surrounding environment (water, noise, air quality, soil, etc.) due to normal operations.

Economic growth: The impact of the proposed operation on potential economic growth in providing stability of both the private sector and public institutions (e.g., business responsiveness, increased availability of consumer goods and services).

Social and political impacts: Changes in local, national, and international power balance (including consequences of proliferation and of increased power of experts, business, and political groups).

Impacts on human resources: The impact of the proposed operation on accessibility and preservation of recreational, cultural, historical, and archeaological reserves surrounding the facility.

Psychological impacts: The psychological impact of the proposed facility on the surrounding communities (fears, worries, concerns of parents, etc.). Alienation of the community from leadership (government, experts, business, etc.).

Day to day system reliability: The adequacy of the proposed system to supply basic energy requirements and preventing brownouts, blackouts, and loss of load.

Overall system stability and efficiency: The ability of the proposed operation to adapt to diversity of fuel supplies and co-generation requirements. Also included are considerations of adequacy of the scale to meet the projected needs of the community, and the time scale to commission and subsequent decommission of the operation.

Direct electricity costs--consumption: The impact of the proposed facility on operational and short term costs that are to be absorbed by the consumer through the projected increase of the ¢/KWh charge.

Sales and returns: The impact of the proposed facility on sales and returns to the utility company.

Indirect electricity costs: The impact of the proposed operation on costs associated with shutdowns, waste storage, reclamation, regulation, accidents, brownouts, blackouts, energy conversions, and on-going energy research and development.

Procedure. Subjects were run individually. They were familiarized with the energy scenario, the value tree, and the options in a booklet describing the problem. Attribute definitions were provided on cue cards, so that subjects could refer to them throughout the task. Subjects were instructed that responses should reflect their own beliefs and preferences about risks and benefits of alternative sources of electricity supply and thus there were no right or wrong answers. They required about 1½ hours to complete all tasks.

The subjects' first task was to rate each of the three energy supply options at each of the 22 nodes of the value tree, starting with 13 twig level attributes and moving up. Finally, each subject made an overall rating of the value of the three supply options. All ratings were made in the following way: Subjects first decided which option was the best on an attribute and gave it a value of 100. Next, they decided which option was worst on that attribute, giving it a value of 0. The remaining option was placed somewhere between 0 and 100, such that its position expressed their belief of the standing of that option relative to the other two.

Subjects next performed either the hierarchical or non-hierarchical weighting task. The order of these tasks was randomized across subjects. The hierarchical procedure asked subjects to judge importance ratios for pairs or triplets of attributes as dictated by the structure of the value tree. For instance, each subject was asked to compare "Risk of a major catastrophe" with "Operational impacts on health". Attributes were ranked, the least important attribute given a value of 10, and the other attributes given values preserving the subjects' judgment of the ratios of importance weight. Judgments were required at ten such nodes in the tree (8 pairs and 2 triplets).

The same ratio judgment procedure was followed for non-hierarchical weighting, except that subjects were given all thirteen lowest level attributes at the same time, and they rank-ordered and weighted the entire list simultaneously.

The experimenter then calculated weights, normalized to sum to 1.0, for each of the 13 lowest level attributes from the judgments from both the hierarchical and non-hierarchical assessment procedures. These were presented as a pair of lists side by side with no identification of which list came from which procedure. The subjects were then asked to determine a final set of normalized weights. They were told that they could choose either of the two lists or construct another final weight list, the only restriction being that the final list sum to 1.0.

IV. Results

The first part of our analysis compared the variances of the hierarchical and non-hierarchical weights. For 33 (89%) of the 37 subjects hierarchical weights had a higher variance than non-hierarchical weights. For 30 subjects (81%) the variance of hierarchical weights was more than double the variance of non-hierarchical weights.

The procedure for eliciting final weights was unlike the other two; it simply asked subjects to give a "proportion" of the total weight to each dimension. Thus, judgments were of the "constant sum" rather than ratio-estimation type. In order to compare the ordinal properties of the three weight sets, we computed Kendall tau rank order correlations for each pair of weight vectors and for each subject. The hierarchical and non-hierarchical weight vectors showed only modest ordinal agreement (average tau: .57). Final weights corresponded more closely to the hierarchical weights (average tau: .72) than to non-hierarchical weights

(average tau: .62). Since tau is the proportion of identical pairwise rankings minus the proportion of inverted pairwise rankings, we can conclude that there were approximately 10% more inversions between non-hierarchical and final weights than between hierarchical and final weights.

Next we examined the ability of five different models to predict holistic rank orders of alternatives. The first three models combined the three weighting schemes (hierarchical, non-hierarchical, final) with first level ratings; the fourth model used second level ratings and (hierarchical) second level weights; and the fifth model combined third level ratings with (non-hierarchical) third level weights. The main results, summarized in Table 2, is that there exists only moderate consistency between holistic rankings of alternatives and rankings implied by the composites of the five multiattribute utility models. Different weighting techniques produced about the same amount of inconsistency, and there is no improvement for higher level models.

Insert Table 2 about here

We next examined attribute weights and ratings conditional on subjects' holistic first choice. We identified three groups: the "PRO-NUC(lear)" group (n=10) gave nuclear the higher overall rating, the "PRO-COAL" group (n=12) rated coal the highest, and the "PRO-CONS(ervation)" group (n=15) named the geothermal/conservation package as their preferred option. Table 3 lists the average weights for the three groups and for the hierarchical and non-hierarchical weighting procedures. These average weights show substantial agreement across groups. For example, all groups considered Health/Safety/Environment as the most important factor by far. Finances/Reliability/Stability and Political/Social/Psychological were a distant second and third. None of the weight differences among

TABLE 2

CONSISTENCY BETWEEN HOLISTIC RANKINGS

OF ALTERNATIVES AND MODEL PREDICTIONS

	Correct Predictions of 1st choice (n=37)	Correct Rank Ordering (n=37)	Average tau (n=37)
1st level model			
hier. weights	65%	49%	.46
non-hier. wts.	62%	43%	.42
final weights	65%	39%	.40
2nd level model	62%	41%	.33
3rd level model	57%	38%	.31

groups were significant.

Insert Table 3 about here

Since subjects weight the attributes about the same, no matter what option is holistically preferred, it would seem that the single attribute ratings of the options must differ to explain group differences in holistic ratings. Table 4 shows group averages of the ratings of the three alternatives on all branches and nodes of the tree. Consider the Health/Safety/Environment branch first (Table 4a). In this table we underlined for each

Insert Tables 4a-c about here

group the mean rating that was highest across options (columns). As is evident, there was considerable agreement among the three groups that the Conservation/Geothermal option was best with respect to all Health/Safety/Environment attributes. We also marked with an asterisk the mean rating that was highest across groups (rows). This analysis reveals a trend for a group to favor the option that it prefers holistically. To substantiate these trends, a two-way ANOVA was performed on each 3x3 matrix in Table 4a. As one would expect, the group main effect was insignificant, while the option main effect was significant for all six matrices. The group bias to favor its own option showed as a significant group by option interaction in the "Catastrophe" attribute only.

A similar pattern emerged in the Finances/Stability/Reliability branch (Table 4c). Here groups agreed that nuclear or coal were the best options, while conservation scored lowest. These trends appeared as significant option main effects in all but the direct and indirect cost attributes. The bias to favor the holistically preferred option also emerged as a significant option by group interaction for the

TABLE ˜: IMPORTA!CE WEIGHTS Y GROUPS, I.:ERARCHICAL VS. NON-HIL ARCHICAL (..100)

Attribute	Non-Hierarchical Weights			Hierarchical Weights		
	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS
1. Catastrophe	13	20	14	21	26	20
2. Oper. Health Imp.	14	13	15	19	15	16
3. Flora and Fauna	8	6	7	9	7	8
4. Oper. Env. Impacts	9	8	10	14	9	12
5. Economic Growth	7	7	7	5	6	6
6. Political Impact	5	5	5	2	5	4
7. Human Resources	6	5	5	4	3	5
8. Psych. Impacts	8	5	9	6	3	9
9. Reliability	8	8	7	6	6	5
10. Stability/Efficiency	9	10	9	10	13	9
11. Direct Costs	4	4	5	2	3	2
12. Sales and Returns	3	4	2	1	2	1
13. Indirect Costs	5	5	6	1	2	2
14. Health/Safety (1,2)	NOT ASSESSED			41	40	36
15. Environment (3,4)				23	17	20
16. Political/Econ. (5,6)				7	11	9
17. Social/Psych. (7,8)				9	6	14
18. Stability/Re. (9,10)				16	20	14
19. Costs (11,12,13)				5	7	6
20. Health/Safety/Env. (14,15)	63	57	56	NOT POSSIBLE		
21. Political/Soc./Psych. (16,17)	16	16	24			
22. Financial and Rel. (18,19)	20	21	21			

TABLE 4a

AVERAGE RATINGS OF ALTERNATIVES BY GROUP FOR THE HEALTH/SAFETY/ENVIRONMENT BRANCH

HEALTH/SAFETY/ENVIRONMENT

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	31*	13	10
Coal	28	57*	35
Cons	88	82	93*

HEALTH/SAFETY

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	39*	11	19
Coal	35	63*	34
Cons	68	82	86*

ENVIRONMENT

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	49*	38	30
Coal	30	40*	30
Cons	63	69	91*

CATASTROPHE

PRO-NUC	PRO-COAL	PRO-CONS
28*	0	0
53	80*	54
77	76	100*

OPERATIONAL HEALTH

PRO-NUC	PRO-COAL	PRO-CONS
35*	26	20
35	38*	22
67	85	100*

FLORA/FAUNA

PRO-NUC	PRO-COAL	PRO-CONS
40*	33	31
24	48*	20
87	72	100*

ENV. IMPACT

PRO-NUC	PRO-COAL	PRO-CONS
57*	40	34
18	32*	10
58	82	99*

TABLE 4b

AVERAGE RATINGS OF ALTERNATIVES BY GROUP FOR THE POLITICAL/SOCIAL/PSYCHOLOGICAL BRANCH

POLITICAL/SOCIAL/PSYCHOLOGICAL

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	53*	13	20
Coal	56	93*	60
Cons	49	47	73*

POLITICAL/ECONOMIC

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	90*	63	71
Coal	65*	53	53
Cons	8	43*	33

SOCIAL/PSYCHOLOGICAL

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	29*	4	13
Coal	45	68*	57
Cons	75	75	83*

ECONOMIC			POLITICAL			SOCIAL			PSYCHOLOGICAL		
PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS
93*	78	91	53*	52	52	57*	36	29	53*	52	52
59*	52	49	58*	45	40	36	56*	21	58*	45	40
0	30*	18	37	55	56*	64	70	88*	37	55	56*

TABLE 4c

AVERAGE RATINGS OF ALTERNATIVES BY GROUP FOR THE FINANCES/STABILITY/RELIABILITY BRANCH

FINANCES/STABILITY/RELIABILITY

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	98*	63	75
Coal	59	64*	63
Cons	7	46*	28

STABILITY/RELIABILITY

	PRO NUC	PRO COAL	PRO CONS
Nuclear	90*	60	56
Coal	67	82*	58
Cons	2	22	41*

COSTS

	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	60*	37	40
Coal	55	82*	63
Cons	35	35	55*

	STABILITY/EFFIC.			RELIABILITY		
	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	100*	71	57	98*	56	81
Coal	51	68*	58	60	80*	64
Cons	9	25	48*	0	25*	18

	DIRECT COSTS			SALES & RETURNS			INDIRECT COSTS		
	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS	PRO-NUC	PRO-COAL	PRO-CONS
Nuclear	66*	62	58	96*	63	77	60*	30	32
Coal	50	69*	54	42	46	49*	58	63*	59
Cons	35	33	42*	21	45*	30	36	54	63*

Stability/Reliability attributes. In the Political/Social/Psychological branch the three groups show some agreement that conservation is best in all but the "economic growth" attribute where all groups rated nuclear the highest. All attributes except "political impacts" show a significant option main effect. The option by group interaction is significant only for the "psychological impacts" attribute and for the general value "Political/Social/Psychological".

In summary, we found that the different groups, defined by their holistic first choices, tended to show remarkable agreement on their attribute-wise first choices. Nevertheless, we also detected a tendency in several attributes for the groups to favor the option that they prefer holistically.

To further clarify the differences and similarities among the three groups, we calculated each subject's utilities for the three options based on the five possible multiattribute utility models. The first row of Table 5 shows the average holistic rating for each group; rows 2-6 show the average multiattribute utilities. Note that we cannot directly compare

Insert Table 5 about here

the scale of the calculated utilities with the holistic scale, since the latter was forced to go through the extreme points 0 and 100. However, three of the five multiattribute utility models of the PRO-NUC group favor the Conservation option, and are therefore inconsistent with that group's holistic choice. Further, the PRO-COAL group's multiattribute utilities for coal and conservation are very close. Only the multiattribute utilities of the PRO-CONS group clearly follow the holistic pattern. Composites from higher level models do not resemble holistic ratings more closely than those of lower level models.

TABLE 5

AVERAGE HOLISTIC RATINGS AND AVERAGE UTILITIES

DERIVED FROM INDIVIDUAL MULTIATTRIBUTE MODELS

	PRO-NUC			PRO-COAL			PRO-CONS		
	Nuclear	Coal	Cons.	Nuclear	Coal	Cons.	Nuclear	Coal	Cons.
Holistic	100	54	7	10	100	37	23	37	100
1st level model									
hier. weights	49	46	55	38	59	58	30	37	82
non-hier. weights	54	46	50	38	59	58	34	41	74
final weights	51	47	52	37	61	56	33	37	78
2nd level model	54	43	50	32	66	57	29	43	76
3rd level model	50	39	59	27	66	65	26	44	78

To further investigate this apparent inconsistency between holistic judgments and multiattribute models, we compared model predictions of each subject's first choice and full rank order with holistic assessments separately for each group. The striking result, summarized in Table 6, is that there exists substantial inconsistency for individuals preferring the nuclear option, less for those preferring coal, and very little for those preferring conservation.

Insert Table 6 about here

V. Discussion

This experiment had three basic findings. First, it replicated Sayeki and Vesper's (1973) result that hierarchical weights are steeper than non-hierarchical weights. Second, all multiattribute models showed considerable discrepancies from holistic rankings, independent of the weighting procedure or the level of the tree at which alternatives were rated. However, the degree of inconsistency depended on the subjects' first holistic choice. Third, groups identified by their holistic first choice had very similar multiattribute models. There was little disagreement about weights and only moderate disagreement about the attribute ratings of the energy options, in spite of the obvious disagreement in holistic preferences.

One interpretation of the flatter non-hierarchical weights is that subjects have a response bias against large weight ratios. Since relatively flat higher level weights can still produce steep lower level weights, this response bias would not have affected hierarchical weights as much as non-hierarchical weights.

TABLE 6

CONSISTENCY BETWEEN MULTIATTRIBUTE ORDERINGS

AND HOLISTIC PREFERENCES BY GROUP

Models:	Group: PRO-NUC Correct 1st choice	PRO-NUC Correct rank order	PRO-COAL Correct 1st choice	PRO-COAL Correct rank order	PRO-CONS Correct 1st choice	PRO-CONS Correct rank order
1st level models						
hier. weights	20%	10%	58%	42%	100%	73%
non-hier. weights	30%	30%	58%	33%	87%	60%
final weights	30%	10%	58%	42%	93%	53%
2nd level model	30%	20%	50%	42%	93%	87%
3rd level model	40%	0%	42%	42%	93%	67%

There are several reasons why subjects' holistic rankings and their multiattribute utility models were only moderatley consistent. First, the value tree in Figure 2 may not have represented individual subjects' values; second, ratings may have been distorted or otherwise in error; and third, elicited weights may have differed from the implicit weights underlying holistic rankings.

The value tree in Figure 2 was constructed by pruning and combining separate trees that reflected the values of several political actors in the energy debate. The combined tree therefore provided a rather broad, balanced, and social view of the problem. Had we elicited value trees from each subject, we probably would have found many idiosyncratic and politically motivated structures. While holistic rankings allowed subjects to engage such idiosyncratic perspectives, the value tree may have created a common viewpoint that masked individual factors, while making the social factors more relevant.

Ratings were another potential source of inconsistency. Our subjects were not experts in assessing energy options, and they had to rely on whatever knowledge they possessed when rating options on the attributes. While subjects had some knowledge (or at least opinions) about the relative standing of the three alternatives on most attributes, they were probably not very sure of their judgments in some attributes, and produced very tentative ratings. One would expect that subjects discount such "weak" ratings when making holistic comparisons among alternatives. In principle, the multiattribute models could achieve the same effect by reducing the weight for an attribute about which a subject has little knowledge. But if subjects interpreted weights in terms

of the general social relevance of an attribute, such discounting would not necessarily have occurred. Multiplying relatively whimsical ratings with undiscounted "social relevance" type weights would tend to produce inconsistencies with holistic judgments.

Neither idiosyncratic value structures nor errors in ratings can explain the finding that the three groups (PRO-NUC, PRO-COAL, PRO-CONS) showed substantial differences in the consistency between holistic rankings and the multiattribute models. A possible explanation is that groups perceived the value ranges in the attributes differently. For example, all groups rated the geothermal/conservation option highest on the Health/Safety/Environment attribute, coal being second in most attributes, nuclear third. But the PRO-NUC group may have perceived the differences among options in the Health/Safety/Environment attributes as very small. The PRO-CONS groups, on the other hand, may have perceived very large differences in this set of attributes. The multiattribute utility models supposedly compensate for such differences in perceived value ranges by an appropriate adjustment of attribute weights. Proper adjustment of the weights would have required to lower weights for small perceived value ranges, and increase them for large ones. If, instead, importance judgments were range insensitive, reflecting a general social concern rather than an appropriate re-scaling of attributes, the multiattribute utility models would be distorted.

As mentioned above, the instructions for weight elicitation could have been interpreted by subjects as instructions to assess the general social relevance of the attributes. This interpretation is supported by the finding that most subjects, regardless of group, assigned about 50% of the weights to the socially relevant Health/Safety/Environment attributes.

Assuming that the PRO-NUC subjects perceived the value range in these attributes as relatively small, their weights should have been adjusted downward. Failure to adjust would artificially increase the multiattribute utilities of the conservation/geothermal option which scored highly on these attributes. Such an increase would be in conflict with the holistic preferences of the PRO-NUC group and explain the high rate of inconsistency for that group.

The convergence of multiattribute models across groups was previously reported by Aschenbrenner and Kasubek (1978) and by Gardiner and Edwards (1976). This could be an extremely relevant finding, if it was indeed due to the convergence of view when formulated in a more rational and cognitive manner. It points to the usefulness of multiattribute models for aiding discussions and negotiations between groups involved in controversial and political decisions. These models could be built separately for each adversary group to pinpoint the sources of agreement and disagreement and the need for additional information or new options. From this perspective our results indicate that the resolution of inconsistencies <u>within</u> groups may be as important as the resolution of disagreement across groups. As in our study, such disagreements may be much smaller than the initial controversy might indicate. In particular, we found virtually no disagreements about weights, and only some about ratings of alternatives.

Unfortunately, we cannot exclude the possibility that the convergence of the multiattribute models was due to an artifact of range insensitive importance weights, or perhaps due to distortions of weights and ratings towards "socially desirable" values. The obvious experiment would confront subjects with the inconsistencies between their holistic ratings and their multiattribute models and ask them to resolve them.

VI. References

Aschenbrenner, K.M. and Kasubek, W. Challenging the Cushing syndrome: multiattribute evaluation of cortisone drugs. Organizational Behavior and Human Performance, 1978, 22, 216-234.

Edwards, W. How to use multiattribute utility measurement for social decision making. IEEE Transactions on Systems, Man, and Cybernetics, 1977, 7, 326-340.

Gardiner, P.C. and Edwards, W. Public values: multiattribute utility measurement for social decision making. In M.F. Kaplan and S. Schwartz (eds.), Human Judgment and Decision Processes. New York: Academic Press, 1975.

Keeney, R.L. and Raiffa, H. Decisions with Multiple Objectives: Preferences and Value Tradeoffs. New York: Wiley, 1976.

Saaty, T.L. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, 1977, 3, 234-281.

Sayeki, Y. and Vesper, K.H. Allocation of importance and goal-dependent utility. Management Science, 1973, 19, 667-675.

Slovic, P. and Lichtenstein, S. A comparison of Bayesian and regression approaches to the study of human information processing in judgment. Organizational Behavior and Human Performance, 1971, 6, 649-744.

v. Winterfeldt, D. and Otway, H. Judgments of technologies and their risks. In P. Stichl (ed.), Tasks, Methods, and Predictive Power of Risk Research. London: Ballinger, 1981 (in press).

VII. Reference Notes

1. John, R.S. and Edwards, W. Importance weight assessment for additive, riskless preference functions: a review. Technical Report No. 78-5, Social Science Research Institute, University of Southern California, 1978.

VIII. Footnotes

[1]This research was supported by the Advanced Projects Research Agency of the Department of Defense, prime contract MDA 903-80-C-0194 (ARPA), and subcontracted from Decisions and Designs, Inc., #79-312-0731. The value trees were constructed in a separate project supported by SANDIA Laboratories under contract no. 42-4109.
The authors would like to thank Ward Edwards, Jim Anson, and Greg Griffin for helpful comments and criticisms.

[2]2400 MW provide the electricity supply for a major city, and it was explained that it would meet the required demand.

CONTRACT DISTRIBUTION LIST
(Unclassified Technical Reports)

Director Advanced Research Projects Agency Attention: Program Management Office 1400 Wilson Boulevard Arlington, Virginia 22209	2 copies
Office of Naval Research Attention : Code 455 800 North Quincy Street Arlington, Virginia 22217	3 copies
Defense Technical Information Center Attention: DDC-TC Cameron Station Alexandria, Virgina 22314	12 copies
DCASMA Baltimore Office Attention: Mrs. Betty L. Driskill 300 East Joppa Road Towson, Maryland 21204	1 copy
Director Naval Research Laboratory Attention: Code 2627 Washington, D.C. 20375	6 copies

Commander, Rome Air Development Center
Attention: Mr. John Atkinson
Griffins AFB
Rome, NY 13440

Other Government Agencies

Chief, Strategic Evaluation Center
Central Intelligence Agency
Headquarters, Room 2G24
Washington, D.C. 20505

Director, Center for the Study of Intelligence
Central Intelligence Agency
Attention: Mr. Dean Moor
Washington, D.C. 20505

Office of Life Sciences
Headquarters, National Aeronautics and Space Administration
Attention: Dr. Stanley Deutsch
600 Independence Avenue
Washington, D.C. 20546

Other Institutions

Institute for Defense Analyses
Attention: Dr. Jesse Orlansky
400 Army Navy Drive
Arlington, VA 22202

Perceptronics, Incorporated
Attention: Dr. Amos Freedy
6271 Variel Avenue
Woodland Hills, CA 91364

Stanford University
Attention: Dr. R. A. Howard
Stanford, CA 94305

Department of Psychology
Brunel University
Attention: Dr. Lawrence D. Phillips
Uxbridge, Middlesex UB8 3PH
England

Decision Analysis Group
Stanford Research Institute
Attention: Dr. Miley W. Merkhofer
Menlo Park, CA 94025

Decision Research
1201 Oak Street
Eugene, OR 97401

Department of Psychology
University of Washington
Attention: Dr. Lee Roy Beach
Seattle, WA 98195

Department of Electrical and Computer Engineering
University of Michigan
Attention: Professor Kan Chen
Ann Arbor, MI 94135

Dr. Amos Tversky
Department of Psychology
Stanford University
Stanford, California 94305

Dr. Andrew P. Sage
School of Engineering and Applied Science
University of Virginia
Charlottesville, VA 22903

Professor Howard Raiffa
Morgan 302
Harvard Business School
Harvard University
Cambridge, MA 02163

Department of Psychology
University of Oklahoma
Attention: Dr. Charles Gettys
455 West Lindsey
Dale Hall Tower
Norman, OK 73069

Institute of Behavioral Science #3
University of Colorado
Attention: Dr. Kenneth Hammond
Room 201
Boulder, Colorado 80309

Decisions and Designs, Incorporated
Suite 600, 8400 Westpark Drive
P.O. Box 907
McLean, VA 22101

Decision Science Consortium, Inc.
Suite 421
7700 Leesburg Pike
Falls Church, VA 22043

Dean of Research Administration
Naval Postgraduate School
Attention: Patrick C. Parker
Monterey, CA 93940

Naval Personnel Research and Development
Center (Code 305)
Attention: LCDR O'Bar
San Diego, CA 92152

Navy Personnel Research and Development
Center
Manned Systems Design (Code 311)
Attention: Dr. Fred Muckler
San Diego, CA 92152

Director, Center for Advanced Research
Naval War College
Attention: Professor C. Lewis
Newport, RI 02840

Naval Research Laboratory
Communications Sciences Division (Code 54)
Attention: Dr. John Shore
Washington, D.C. 20375

Dean of the Academic Departments
U.S. Naval Academy
Annapolis, MD 21402

Chief, Intelligence Division
Marine Corps Development Center
Quantico, VA 22134

Department of the Army

Deputy Under Secretary of the Army
(Operations Research)
The Pentagon, Room 2E621
Washington, D.C. 20310

Director, Army Library
Army Studies (ASDIRS)
The Pentagon, Room 1A534
Washington, D.C. 20310

U.S. Army Research Institute
Organizations and Systems Research Laboratory
Attention: Dr. Edgar M. Johnson
5001 Eisenhower Avenue
Alexandria, VA 22333

Technical Director, U.S. Army Concepts
Analysis Agency
8120 Woodmont Avenue
Bethesda, MD 20014

Director, Strategic Studies Institute
U.S. Army Combat Developments Command
Carlisle Barracks, PA 17013

Department of Engineering
United States Military Academy
Attention: COL A. F. Grum
West Point, NY 10996

Chief, Studies and Analysis Office
Headquarters, Army Training and
Doctrine Command
Ft. Monroe, VA 23351

Department of the Air Force

Assistant for Requirements Development
and Acquistion Programs
Office of the Deputy Chief of Staff
for Research and Development
The Pentagon, Room 4C331
Washington, D.C. 20330

Air Force Office of Scientific
Research
Life Sciences Directorate
Building 410, Bolling AFB
Washington, D.C. 20332

Commandant, Air University
Maxwell AFB, AL 36112

Chief, Systems Effectiveness Branch
Human Engineering Division
Attention: Dr. Donald A. Topmiller
Wright-Patterson AFB, OH 45433

Deputy Chief of Staff, Plans, and
Operations
Directorate of Concepts (AR/XOCCC)
Attention: Major R. Linhard
The Pentagon, Room 4D 1047
Washington, D.C. 20330

SUPPLEMENTAL DISTRIBUTION LIST
(Unclassified Technical Reports)

Department of Defense

Director of Net Assessment
Office of the Secretary of Defense
Attention: MAJ Robert G. Gough, USAF
The Pentagon, Room 3A930
Washington, D.C. 20301

Assistant Director (Net Technical Assessment)
Office of the Deputy Director of Defense
Research and Engineering (Test and
Evaluation)
The Pentagon, Room 3C125
Washington, D.C. 20301

Director, Cybernetics Technology Division
Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

Chairman, Department of Curriculum
Development
National War College
Ft. McNair, 4th and P Streets, SW
Washington, D.C. 20319

Defense Intelligence School
Attention: Professor Douglas E. Hunter
Washington, D.C. 20374

Vice Director for Production
Management Office (Special Actions)
Defense Intelligence Agency
Room 1E863, The Pentagon
Washington, D.C. 20301

Command and Control Technical
Center
Defense Communications Agency
Attention: Mr. John D. Hwang
Washington, D.C. 20301

Department of the Navy

Office of the Chief of Naval
Operations
(OP-951)
Washington, D.C. 20450

Office of Naval Research
Assistant Chief for Technology
(Code: 200)
800 N. Quincy Street
Arlington, VA 22217

Office of Naval Research (Code 230)
800 No. Quincy Street
Arlington, VA 22217

Office of Naval Research
Naval Analysis Programs (Code 431)
800 No. Quincy Street
Arlington, VA 22217

Office of Naval Research
Operations Research Programs (Code 4
800 No. Quincy Street
Arlington, VA 22217

Office of Naval Research
Information Systems Program (Code 43
800 No. Quincy Street
Arlington, VA 22217

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
(Code RD-1)
Washington, D.C. 20380